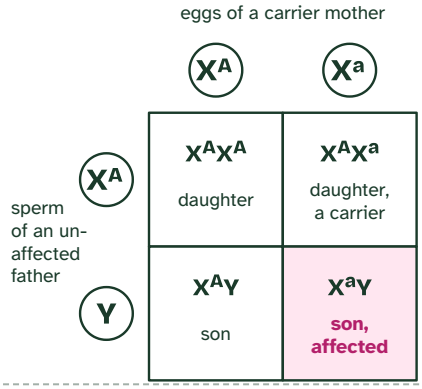
AP BIOLOGY | UNIT 5 | TOPICS 5.4 AND 5.5 | REVISION ON TWO PAGES

When the ratio *breaks*

What to know, what to draw and what to say. Nothing else.

THE ONE IDEA

A ratio that fails chi-square is a clue: to how alleles show, where a gene sits, or what the environment does to its expression.



Draw it like this. Write the allele on the X and leave the Y bare: it has no copy of the gene.

5.4.A SEX-LINKED TRAITS

A gene on the *X chromosome*

- **Sex-linked** traits are set by genes on the sex chromosomes: X-linked or Y-linked.
- An XY individual has one X, so a single recessive allele on it shows. An XX individual needs the allele on both. So X-linked recessive traits appear at **higher rates in XY individuals**.
- A father gives his X to every daughter and his Y to every son, so he never passes an X-linked allele to a son. A Y-linked trait goes from a father to all his sons.
- In data, a ratio that **differs between sons and daughters** points to a sex-linked gene.

X-LINKED RECESSIVE IN A PEDIGREE: THREE SIGNS

M **Males** mostly males are affected

M **Mothers** unaffected carrier mother, affected son

N **Never** father to son: a son gets his Y

5.4.A SPOTTING A DEVIATION

A ratio that *will not fit*

- Mendel's ratios are a model. Many traits do not follow them.
- A deviation is found in data: the **observed ratio differs statistically** from the predicted one. The test is chi-square.
- The null hypothesis is the Mendelian ratio. Chi-square above the critical value: **reject** it.
- Rejecting does not name the cause. Alleles still segregate: something else is outside the model.

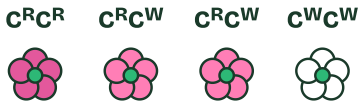
Worked 3 : 1 predicted
160 offspring: 100 tall and 60 short, against 120 and 40 expected. Chi-square = 3.33 + 10.00 = **13.33**.

Verdict 1 degree of freedom
13.33 is above 3.84: reject. These plants do not fit 3 : 1.

5.4.A KINDS OF DOMINANCE

In between, or *both at once*

- **Incomplete dominance**: neither allele masks the other, so the heterozygote is **in between**. Red × white four o'clocks give pink.
- **Codominance**: both alleles' phenotypes are expressed. A roan Shorthorn has red hairs and white hairs side by side.
- Either way, two heterozygotes give three phenotypes, **1 : 2 : 1**, not 3 : 1. Neither allele is recessive, so both take capitals: C^R and C^W.
- The alleles never blend: cross two pinks and red and white come back.



offspring of pink × pink

5.4.A BIRDS AND BEES

Sex without *X and Y*

- In some species sex is not set by X and Y chromosomes.

Birds Z and W
Males are ZZ and females are ZW, so a recessive allele on the Z shows more often in females.

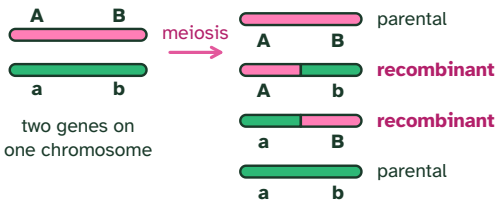
Bees haplodiploidy
Females grow from fertilized eggs and are diploid. Males grow from unfertilized eggs and are haploid.

- The rule to carry over is not "males show it more". It is: the sex with **one copy** of the gene shows a recessive allele more often.
- A male bee has one set of chromosomes, so every allele he carries shows.

5.4.A TWO GENES, ONE CHROMOSOME

Linked genes and map distance

- Genes on the same chromosome are **genetically linked**. They tend to segregate together, so they do not assort independently.
- Only **crossing over** between the two genes separates their alleles. A test cross gives two large parental classes and two small recombinant ones, not 1 : 1 : 1 : 1.
- **Recombination frequency** = recombinants ÷ total × 100, and 1% is **1 map unit**. Genes farther apart are separated more often.



Worked 1,000 offspring
430 and 420 parental, 70 and 80 recombinant. 150 ÷ 1,000 × 100 = 15%: **15 map units**.

Order three genes
A to B is 12, B to D is 5, A to D is 17. So B lies between A and D.

Pleiotropy, organelle DNA and the *environment*

5.4.A TRAITS THAT NEVER PART

Pleiotropy: one gene, many effects

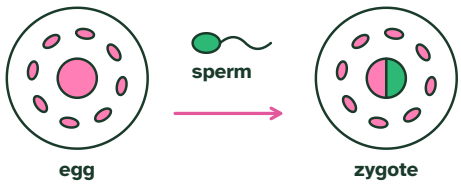
- **Pleiotropy**: the expression of a single gene results in multiple traits, because its product acts in more than one place or pathway.
- Those traits **do not segregate independently**. They are inherited as a set, and no crossover can part them: there is only one gene.
- In Mendel's peas one gene colors the flower, the seed coat and the leaf joints: it switches on the pathway for one purple pigment.

TWO TRAITS FROM	PHENOTYPE CLASSES IN A CROSS
Two genes on different chromosomes	Four: 9 : 3 : 3 : 1 from two heterozygotes.
Two linked genes	Four, with the two recombinant classes small.
One pleiotropic gene	Two only. The traits always go together.

5.4.A NON-NUCLEAR INHERITANCE

DNA *outside the nucleus*

- Mitochondria and chloroplasts have their own DNA. Traits set by it **do not follow Mendel's rules**.
- These organelles are **randomly assorted** to gametes and daughter cells, not lined up and shared out as chromosomes are. So there is no fixed ratio.
- **Animals:** mitochondria come from the egg, not the sperm, so mitochondrial traits are **maternally inherited**.
- **Plants:** mitochondria and chloroplasts come in the ovule, not the pollen, so their traits follow the mother plant too.

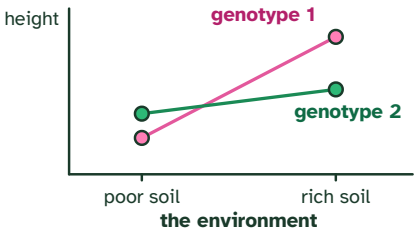


Nuclear DNA is half from each parent. The mitochondria, and their DNA, are all from the egg.

5.5.A PHENOTYPIC PLASTICITY

Same genotype, *different phenotype*

- **Environmental conditions influence gene expression**. So the same genotype can give different phenotypes in different conditions: **phenotypic plasticity**.
- The DNA sequence does not change. What changes is which genes are expressed, and how much. The change happens within one individual's life and is not passed on in its alleles.
- To explain a case, make three moves: the genotype is the same, an environmental condition differs, and the phenotype responds.
- On a graph each line is one genotype. A sloping line shows plasticity; different slopes show that genotypes respond differently.



NUTRITION	SOIL PH	SEASON	NEST HEAT	UV LIGHT	MATE NEARBY
Humans Height and weight.	**Some flowers** Blue or pink.	**Arctic animals** White or brown fur.	**Reptiles** Male or female.	**Animals** More melanin.	**Yeast** Pheromone made.

WATCH OUT

Five mistakes that *cost points*

- ✕ **Incomplete dominance blends the phenotype, not the alleles.** Cross two pinks and red and white come back.
- ✕ **Linked is not sex-linked.** Linked genes share any one chromosome; sex-linked genes sit on a sex chromosome.
- ✕ **Add both recombinant classes before you divide.** One class alone gives half the true distance.
- ✕ **Maternal inheritance is not X-linked.** A father passes his X to daughters, but his mitochondria to no one.
- ✕ **The environment changes expression, not the genes.** Plasticity is not mutation, and it is not evolution.

COVER THE SHEET

Can you *answer these?*

1. Explain how a deviation from 3 : 1 is identified in data.
2. Describe the coat of a codominant heterozygote.
3. Predict the sons of an affected mother, X^aX^a.
4. Explain why linked genes do not assort independently.
5. Calculate the map distance: 104 recombinants in 800.
6. Explain why a pleiotropic gene gives no recombinants.
7. Predict the children of a man with a mitochondrial trait.
8. Justify: a fox's winter coat is not passed to its pups.

IN THE EXAM

Read the cause from the data: sexes differ, sex-linked; two large and two small classes, linked; three phenotypes in 1 : 2 : 1, incomplete dominance or codominance. Name it, then show the working.

GO FURTHER

Animated figures, a dry lab and a marked Check are in the full guide online.